estimates from rough measurements that the depth of the cloud from top of dome to base is from 3,000 to 5,000 feet.

NOTE.—The type of cloud described in the foregoing article has been named *crest-cloud* by W. J. Humphreys, who says, in his "Physics of the Air" (Jour. Frankl. Inst., May. 1918, p. 635):

The crest cloud is formed by the upward deflection of the wind by a long mountain ridge. It usually covers the higher slopes as well as the top, and though called cloud by people in the valleys below, is likely to be designated fog by any one actually in it. Occasionally condensation occurs only along the upper reaches of the deflected winds, in which case the cloud belt is above and to the leeward of the mountain ridge.

In either case the individual droplets are quickly evaporated and the cloud form preserved only through continuous condensation from renewed air. It is permanent in the same sense that a cataract is permanent through the continuous supply of water by the stream above.

Identical in mode of origin with the crest-cloud is the *cap-cloud* or *cloud-cap*, formed over an isolated peak.

These clouds, due to the forced ascent, of moist air over mountains, were once known as *parasitic clouds*—a term introduced by Marcellin du Carla in his memoir "Sur les nuages parasites" (Rozier, Observations sur la physique, etc., v. 24, 1784, p. 392–399; 456–473; v. 25, 1784, p. 31–38; 94–102). This author describes the occurrence of the clouds in question in various parts of the world and endeavors to explain them as due to condensation in an updraft of air caused by the emission of subterranean heat from mountains. In the Annales de la Société d'agriculture de Lyon, v. 2, 1839, there is an account of a cloud of this type as observed on the summit of Mont Pilat, south of Lyons. ("Note sur le développement d'un nuage parasite au Pilat.") In his book on "The Mediterranean" (London, 1854), p. 235, Admiral W. H. Smyth says that during the development of the solano at Cadiz "parasitic clouds, as they are termed by meteorologists, cap the hills of Medina Sidonia."

Of the more important local examples of such clouds it is necessary to mention here only the Helm Cloud of the English Lake District, and the Table Cloth of Table Mountain, South Africa; both famous in meteorological literature.

An excellent specimen of the crest-cloud is the so-called *foehn-wall* (*Föhnmauer*), seen along the crest of an Alpine ridge over which a foehn is blowing. This is described and illustrated in Dr. F. Kerner von Marilaun's paper "Die Föhnmauer" (Ztschr.Deutsch. u. Oesterr. Alpenvereines, v. 23, 1892).—*C F. Talman.*

SOME NEW FACTS ABOUT THE CENTERS OF TYPHOONS.

By CO-CHING CHU.

[Dated: Cambridge, Mass., June 15, 1918.]

TEMPERATURE CONDITIONS IN THE CENTER OF A TYPHOON.

No problem connected with the study of tropical cyclones is more interesting and more vital than that which concerns the "eye" of the storm. The "eye" is the central region of relative or absolute calm. The calm may last a few minutes, or more than an hour. Immediately after the period of calm, the wind at once regains its strength, and blows with hurricane force from a direction nearly or exactly opposite to that from which it came before the calm. Some years ago, Sidney M. Ballou made an investigation of the phenomenon of the eye of the storm.[1] He gave several authoritative accounts of the phenomenon as observed before 1892, and suggested the probable explanations for its existence. Since then, however, many additional accounts of the eye of the storm have found their way into the reports of the different observatories and meteorological services, and a complete analysis of these would doubtless throw much more light on the subject. The present paper can deal with only a few of the accounts which have been given in the Monthly Bulletins of the Philippines Weather Bureau during the years 1904–1915. We will discuss first the temperature conditions in the center of a typhoon.

It is to be regretted that readings of the thermometers are not always given in the reports of the phenomena associated with the passage of the eye of the storm. A knowledge of the temperature condition in the eye is necessary in order to understand many other phenomena, like the clearing of the sky, etc, which are related to the passage of the calm center.

Regarding the temperature condition of the atmosphere during the passage of the central calm in the famous Manila typhoon of October 18, 1882, Father Algué says:[2]

When at noon on the 20th of October, 1882, Manila entered the central part of the vortex, the absolute calm, the temperature suddenly rose during its passage from 25°C. (77°F.) to 31.5°C. (88.7°F.), but fell again to its former level after the center had passed the city. This is a change which is exceptional, for no such rise was noticed either on the 5th of November, 1882, at Manila, or, as far as we know, on any other occasion. It, therefore, attacted the attention of meteorologists, and gave rise to various controversies, in which each one took the example to support his own view. Faye also made use of this change of temperature to prove the existence of descending air currents in the interior of cyclones.

After a close examination of all the circumstances we will find that the temperature remained steady and comparatively low from 7 p. m. on the 19th till a little before the transit of the center—that is to say, during the time in which the rain squalls were almost incessant and the gusts of wind freshened until they reached the force of a cyclonic storm. This steady, low temperature is without any doubt to be ascribed to the showers and wind squalls. According to the regular oscillations of temperature on cloudy days, the thermometers had to fall during the afternoon of October 19, since during that month the normal temperature for 7 p. m. does not reach 26°C. (78.8°F.). After that hour the temperature decreases very slowly to 24°C. (75.2°F.) at midnight, and then remains fairly constant until 7 a. m. It is, therefore, nothing extraordinary if, from 7 p. m. of October 19 to 7 a. m. of October 20, the temperature remained slightly below 25°C. (77°F.). Usually, indeed, on cloudy days the thermometer rises between 7 a. m. and noon to 27°C. (80.6°F.), but during these hours on October 20 the winds were already more than brisk, the squalls frequent, the rain heavy and continually increasing until the entrance into the relative central calm. At this moment the dense covering of the nimbus grew lighter, the squalls ceased, the wind calmed down, the sky became almost clear; Manila was within the extended region of vortical calm of about 14–16 miles diameter. What wonder, then, that without any other cause but solar activity from a sky nearly clear, by simple radiation, the temperature rose rapidly till it reached the normal height, which is 31.5°C. (88.7°F.) for a cloudless day in October?

Discussing the same subject, Hann says:[3]

Merkliche Änderungen der Temperatur und Feuchtigkeit im Zentrum einer Zyklone werden nur bei jener vom 20. Oktober, 1882, zu Manila angegeben, wo die Temperatur auffallend stieg und die relative Feuchtigkeit abnahm. Bisher ist kein gleicher Fall berichtet worden.

During the years 1904–1915 at least four cases of an increase of temperature during the passage of the central calm of typhoons have been found. Indeed, in one case the rise of temperature was more remarkable than even that during the celebrated Manila storm of 1882. This occurred on September 16, 1912, at Taito, Formosa. Between 8 and 9 p. m. of the 16th, the minimum reading

[1] *Sidney M. Ballou*, "The Eye of the Storm." American Meteorological Journal 1892, 9:67–82, 121–127.
[2] *Algué*, "Cyclones of the Far East," p. 63.
[3] "Lehrbuch der Meteorologie," Leipzig, 1915, p. 596.

of the barometer was 712.4 mm. (28.05 in.) and coinciding with this minimum, there was a rise of 10.5C. (19.°F.), from 24.1°C.· (75.4°F.) to 34.6° C. (94.1°F.) in temperature, as recorded by the thermograph during the short interval of one hour. From 10 p. m. to midnight the temperature fell about 8° C. (14.4°F.).[4] A copy is here reproduced from the monthly Bulletin of the Philippine Weather Bureau of the barograph and thermograph curves which were furnished to the Manila Observatory by the director of Taihoku Observatory, Formosa. This typhoon originated at lat. 16° N.;

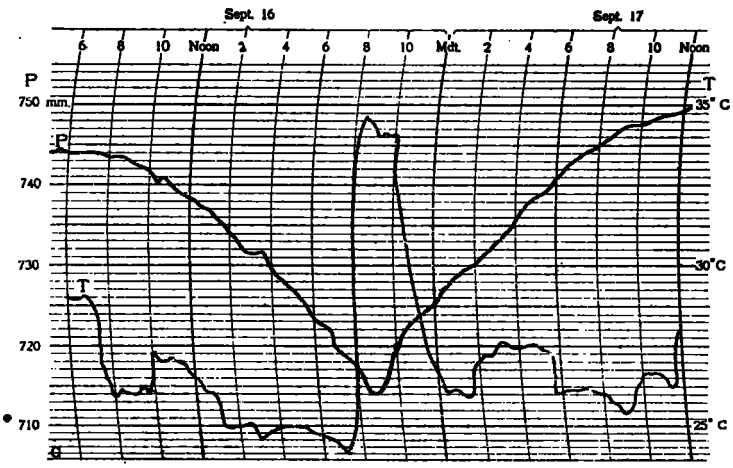

FIG. 1.—Barograph and thermograph curves at Taito, Formosa, September 16–17, 1912.

long. 138° E. on September 10, 1912. It crossed the Island of Formosa on the night of the 16th, and landed on the Chinese coast, south of Foochow, on the morning of the 17th. Aside from the remarkable increase of temperature during the passage of the eye of this storm, it will be remembered as one of the most notable typhoons in the annals of the cyclones of the Far East. The wind velocities recorded at Taito and Tainan, both in Formosa, were the highest since the establishment of the meteorological stations there, in January, 1901, and January, 1897, respectively. As the result of the storm, 107 persons were killed, 293 injured, 91,400 houses were utterly demolished, and 115,700 houses partly destroyed. The English steamer *Dacre Castle* and the Japanese steamer *Hanyestsu Maru* were both wrecked.

Other details with regard to the passage of the calm, the diameter of the calm area, the clearing of the sky, etc., at Taito are not given, either in the Philippine reports or in the Japanese Meteorological Journal. Whether the relative humidity decreased during the time that the temperature was rising is not known, but it probably did. In examining the thermograph curve of Taito, attention should be directed to the fact that the increase of temperature took place at 8–9 p. m., and not at midday, as was the case in the Manila typhoon of 1882. Therefore, Father Algué's objection to the theory of descending air currents in the central calm area, as quoted above, does not hold in this case. For even granting that the sky cleared at Taito between 8 and 9 p. m. of the 16th, no possible radiation could have been received at the place to increase the temperature in the eye of the storm to the extent of 10° C. Indeed, a clear sky in this case would have just the opposite effect, as it would accelerate nocturnal radiation and hence decrease the atmospheric temperature. As will be seen later, this is not the only case where the increase of temperature in the eye of the storm happened to come in the late evening or early morning hours. Unless, therefore, a more satisfactory hypothesis than that of Father Algué's can be offered to explain such cases, we shall be obliged to accept the theory of descending currents in the eye as the most plausible solution of the problem.

Another case of increase of temperature in the central calm occurred in the typhoon of July 12–16, 1909. Mr. A. Beljonne, assistant meteorologist at Phulien Observatory, Indo-China, in describing this storm states:[5]

At 3:30 a. m. (16th) the wind inclines toward north by west, and then veers successively to north by east and northeast; violent squalls continue until about 4:20 a. m. * * * During this interval, disturbed by some wind squalls, the rain was reduced to a few drops and there passed several minutes of relative calm. At the time of the passage of the vortex (pressure 725.3 mm. or 28.55″), a rather unusual phenomenon manifests itself, to wit, an increase of temperature. From 3:04 to 4:09 a. m. the thermometer rose from 22.7° C. (72.9° F.) to 25° C. (77° F.), thus confirming in part the hypothesis of a local and exceptional descending movement of the air of higher strata.

Mr. Beljonne added in a footnote to the above report:

The rise of temperature has been observed likewise at Haiphong, as is attested by the thermograph of this station, which between 3 and 4 a. m. rose from 24.9° C. (76.8° F.) to 26.4° C. (79.5° F.). During the passage of the center the clouds must have been merely reduced to a thin covering. In fact, we have not noticed any clearing of the sky such as by common consent is called the "eye of the storm;" not a single star has been visible at Phulien during that time. Although there was a rise in temperature, this failed to produce a corresponding diminution of the relative humidity, the hygrograph of the observatory continued to register the degree of saturation.

The third case happened during the typhoon of Cagayan de Luzon, October 9–14, 1908, which produced a flood in Luzon the like of which was unknown in that region. The increase of temperature was recorded at Aparri in the afternoon of October 13 during the passage of the relative calm. We quote here the report given by M. Manuel Delago, observer at Aparri.[6]

From 4 a. m. of the 13th the gusts from NNW. had a velocity of more than 50 miles per hour and the barometric fall was extremely alarming. * * * At 10:45 a. m. the barometer read 716.29 mm. (the minimum) and then began to rise rapidly, with winds from the NNE. to E. and sky overcast; from 12 to 2 p. m. there was a kind of relative calm alternating with gusts from the E. and SE., during which the rain slackened. A little after 2 p. m. the wind freshened again from the SE., with clear sky in the southeastern and southwestern quadrants; the rain ceased and the wind was hot and dry; I could not observe the temperature, as the thermometers were destroyed. The thermometer attached to the barometer rose from 25° to 27° C., although it was not exposed to the air.

The last case occurred in the typhoon of May 24–28, 1906, which, according to the Manila report, was one of the most violent storms of the month of May. The increase of temperature in the central calm was registered on board the steamship *Fathomer*, anchored in Lamit Bay, Ambos Camarines, Philippine Islands. The following account is taken from the log of the *Fathomer* as published in the Monthly Bulletin of the Philippine Weather Bureau:[7]

May 26: The vortex came about 1:15 (a. m.), without any shifting of the wind; the abatement of the wind was gradual, the zone of relative calm lasting about 5 minutes. By this time the force of the wind was less than 1 from N. From this time until 2:20 the force was less than 1, veering gradually through the W. to SE. At times the calm was so perfect as to produce hardly any deflection in tobacco smoke. Some slight rain fell during the passage of the center. The sky did not clear, but broke and lightened visibly to the eastward.

* * * Systematic thermometric readings were not taken during the passage of the storm, but just before the advent of the center the thermometer read between 82° and 83° F. At the center this rose to between 85° and 86° F., and after the center passed fell again, reaching a somewhat lower temperature than before, being about 77° to 78° F.

[4] Monthly Bulletin of the Philippine Weather Bureau, September, 1912, pp. 263–265.

[5] Monthly Bulletin of the Philippine Weather Bureau, July, 1909, p. 220.

[6] Monthly Bulletin of the Philippine Weather Bureau, October, 1908, p. 371.

[7] May, 1906, p. 120.

This latter may have been partly due to the natural temperature change, as the temperature would reach a minimum just before daylight.

It is to be noted that no systematic thermometer readings were made during the passage of the calm center from 1:10 a. m. to 2:20 a. m.[8] Hence, the reading of 86° F. (30° C.) may not have been the highest temperature which was reached during that interval. Granting that it was, the increasing of temperature from 1 a. m. to the maximum temperature (between 1:10 a. m. and 2:20 a. m.) was 1.7° C. (3° F.) and the decrease of temperature from that time to 3 a. m. was 4.4° C. (8° F.).

So far as the writer has been able to determine, no other occurrence of an increase of temperature in the eye of a typhoon was recorded on board a steamship at sea during the years 1904–1915. One case was, however, mentioned by Father Algue in "The Cyclones of the Far East." In discussing the hurricane wave, Father Algue referred to the typhoon of August 16 to 18, 1879.[9] The report on this storm is so interesting that the following statements are here included:

The wind continued to stiffen, blowing a hard northeast gale at 4 p. m. (17th). * * * The barometer, falling continually, registered at this hour 746.75 mm., while the thermometer showed 31.1° C., the heat making itself felt intensely. The covering of clouds very dense, low, and threatening; thick, fine rain; the outlook exceedingly limited owing to the darkness. Between 4 and 5 o'clock the wind increased, and finally blew with inconceivable fury. * * * During this hour the barometer fell from 746.75 mm. to 723.89 mm., at 5 o'clock, while the thermometer rose to 32.2°. * * *

At 10 minutes past 5 a sudden calm fell upon us, the barometer showing 721.35 mm., the thermometer 33.3° C. On penetrating into the vertex the furious east-northeast wind had suddenly left us. For two or three minutes we still heard its howling, then reigned silence all around us.

There, within this terrible circle, the waves, seething, towering, of immense bulk, broke over us from every side, each one placing the ship in immediate peril. * * * The gray sky grew lighter here and there, and now and then the sun broke through for a moment as if to illuminate the scene of horror.

According to the above account there was a rise of 1.1° C. (2° F.) in temperature within the short space of 10 minutes just before entering the zone of absolute calm. The increase of temperature in this case may have been due to solar radiation. But since the rise of the thermometer preceded, or at least was simultaneous with, the partial clearing of the sky, it is more likely that both were the effect of the same cause—viz, a gentle descending current.

[8] Loc. cit., p. 121.

[9] *Algue:* "The Cyclones of the Far East," p. 172.